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DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
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RECEIVING ENVIRONMENT STUDIES CONDUCTED IN THE VICINITY OF IONA ISLAND SEWAGE TREATMENT PLANT, VANCOUVER, B.C.

Regional Program Report 83-10

by

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ABSTRACT

The Environmental Protection Service conducted background studies in 1981 and 1982 in an area off the Iona Island sewage treatment plant proposed to receive a deep water extended outfall pipe. Water quality characteristics of salinity, temperature, dissolved oxygen, nutrients and trace metals were measured along with benthic studies relating to sediment particle size, organic and trace metals content and benthic infauna and epifauna. Dives were made with the Pisces IV submersible to visually evaluate substrate stability and general habitat features.

The water column in the study area was affected to a small degree by the existing sewage discharge. Concentration of ammonia in surface waters off the sewage channel were elevated relative to stations to the north and south. Temperature, salinity and dissolved oxygen were characteristic of winter conditions in the Strait of Georgia.

Subtidal sediments were affected to some extent by the existing outfall and by proximity to the Fraser River and estuary. Organic carbon content of the sediment was two to three times the mean of 1.08% suggested for the Strait of Georgia, an indication of organic input from the marshes and from the sewage plant. Industrial discharge to the Fraser River and additions from the sewage plant were probably the source of elevated levels of certain trace metals.

Benthic invertebrate communities in surface sediments were dominated by polychaetes and bivalves with species similar to those recorded at other B.C. coastal locations. Concentrations of certain trace metals in shrimp collected off Iona were comparable to or somewhat greater than other areas on the B.C. Coast receiving domestic sewage discharges as well as other relatively unimpacted areas.

RÉSUMÉ

En 1981 et 1982 le Service de la protection de l'environnement a procédé à des études du milieu dans une zone située au large de l'usine d'épuration des eaux d'égout de l'île Iona, où l'on a prévu d'installer une canalisation de décharge en eau profonde. On a mesuré les caractéristiques de la qualité de l'eau, salinité, température, oxygène dissous, éléments nutritifs, métaux à l'état de traces, en même temps que l'on procédait à des études benthiques sur la dimension des particules sédimentaires, le contenu organique, la présence de métaux à l'état de traces, enfin l'endofaune et l'épifaune. On a procédé à des plongées à l'aide du submersible Pisces IV pour évaluer la stabilité du substrat et les conditions générales de l'habitat.

L'étude a révélé que la colonne d'eau était peu affectée par l'exutoire. La concentration en ammoniaque des eaux de surface à proximité de la conduite de l'exutoire était élevée par rapport aux stations situées plus au nord et plus au sud. La température, la salinité et la proportion d'oxygène dissous résultaient des conditiosn hivernales dans le détroit de Georgia.

On a constaté que les sédiments subtidaux étaient affectés jusqu'à un certain point par l'exutoire et par la proximité du Fraser et de l'estuaire. La proportion de carbone organique trouvé dans les sédiments était de deux à trois fois la proportion moyenne de 1.08% retenue pour le détroit de Georgia, ce qui indiquait la présence d'effluents organiques provenant des marécages et de l'usine d'épuration. Les effluents industriels déversés dans le Fraser et la présence de l'usine d'épuration étaient probablement à l'origine des niveaux élevés de concentration de certaines métaux à l'état de traces.

Les colonies d'invertébrés benthiques vivant dans les couches superficielles de sédiments étaient surtout composées de polychètes et de mollusques bivalves dont les espèces étaient semblables à celles que l'on rencontre en d'autres endroits de la côte de la Colombie-Britannique. La concentration de certains métaux à l'état de traces trouvés dans les crevettes prélevées au large de l'île Iona était comparable, ou quelque peu plus élevée, d'autres points de la côte de la Colombie-Britannique où sont déversés des effluents d'origine domestique ou qui sont relativement peu affectés.

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SUMMARY

1) Surveys were conducted in December, 1981 and March and July, 1982 in the vicinity of the Iona Island sewage treatment plant. Physical and chemical oceanographic features were investigated along with sediment characteristics and benthic faunal communties. The physical nature of the bottom was observed from the Pisces IV submersible.

2) Temperature, salinity and dissolved oxygen water column profiles recorded in December were characteristic of winter conditions in the Strait of Georgia. No oxygen depression existed at the time of sampling with values ranging from a low of 6.6 mg/l at the bottom to 10.0 mg/l at the surface.

3) Dissolved nutrients in the water column were comparable to levels reported for the Strait of Georgia and in areas of other coastal sewage outfalls. Concentrations of ammonia in surface waters off the existing sewage channel were elevated relative to other stations suggestive of an effluent effect.

4) Subtidal surface sediments in the study area were composed primarily of particles less than 62.5 μm. The percent composition of this fraction ranged from 52 to 84% of a sediment sample with stations north of the existing sewage channel having the highest percentages. Organic carbon content of the sediment ranged from 2.8% to 4.9% with higher values again recorded to the north. Flow from the sewage channel and the middle arm of the Fraser under the influence of a prevailing northerly current off Iona could account for these spatial variations. Organic loading from the sewage plant and from the extensive marshlands of the Fraser result in an elevated organic content averaging 3.8% compared to a mean of 1.08% for the Strait of Georgia.

5) Mean concentrations of certain trace metals (Cu, Ni, Zn, Mn, Fe) in surface sediments in the study area were higher than those recorded at other sewage outfalls on the B.C. coast. Industries discharging to the Fraser probably contribute to increased metals along with additions from the sewage treatment plant.

6) The species of benthic invertebrates separated from sediment grabs were similar to those recorded along the B.C. coast. Polychaetes and bivalves were dominant and the invertebrate community as a whole did not appear adversely affected by the existing outfall.

7) Mean trace metal concentrations in shrimp tissue at Iona were comparable to or somewhat greater than values reported for other B.C. areas receiving domestic sewage as well as those considered relatively unimpacted by industrial activity.

8) PISCES IV observations indicate the substrate in the study area to be level and uniform, consisting of unconsolidated mud. Shrimp, crab and limited numbers of fish increase in abundance with decreasing depth.

9) Further studies off Iona are required to more accurately document the exact environmental impacts which the present discharge has had on the benthic habitat in the region of the proposed extended submarine outfall. More information on tissue trace metal and organic levels in resource species is required.

1. INTRODUCTION

The Iona Island Sewage Treatment Plant is located on Iona Island close to the mouth of the North Arm of the Fraser River (Figure 1). The plant currently provides effective primary treatment for flows up to 400 cfs. Effluent has been discharged directly onto Sturgeon Bank at the head of an open sewage channel since 1963. The result of this has been increasing habitat degradation documented in the area south of the Iona jetty (Figure 1). Fish kills due to depressed dissolved oxygen levels, changes in sediment invertebrate species and buildup of decomposing organics and levels of trace metals and organic contaminates are some of the effects recorded to date in the intertidal zone.

A deep sea outfall has been proposed as one step towards improving conditions in the near shore receiving environment. The suggested outfall would extend out from the existing jetty in a north-westerly direction for some 2.5 km, ending in about 70 m of water (Figure 1). The lack of baseline environmental data in the area of the proposed outfall prompted the Environmental Protection Service to conduct surveys in 1981 and 1982. Water quality (salinity, temperature, dissolved oxygen and nutrients) and sediment characteristics (particle size, organic and trace metal content) were measured. Species composition of grab and otter trawl samples were determined as were background tissue trace metal levels. The Geological Survey of Canada participated, providing data on substrate stability and suitability for pipe installation.

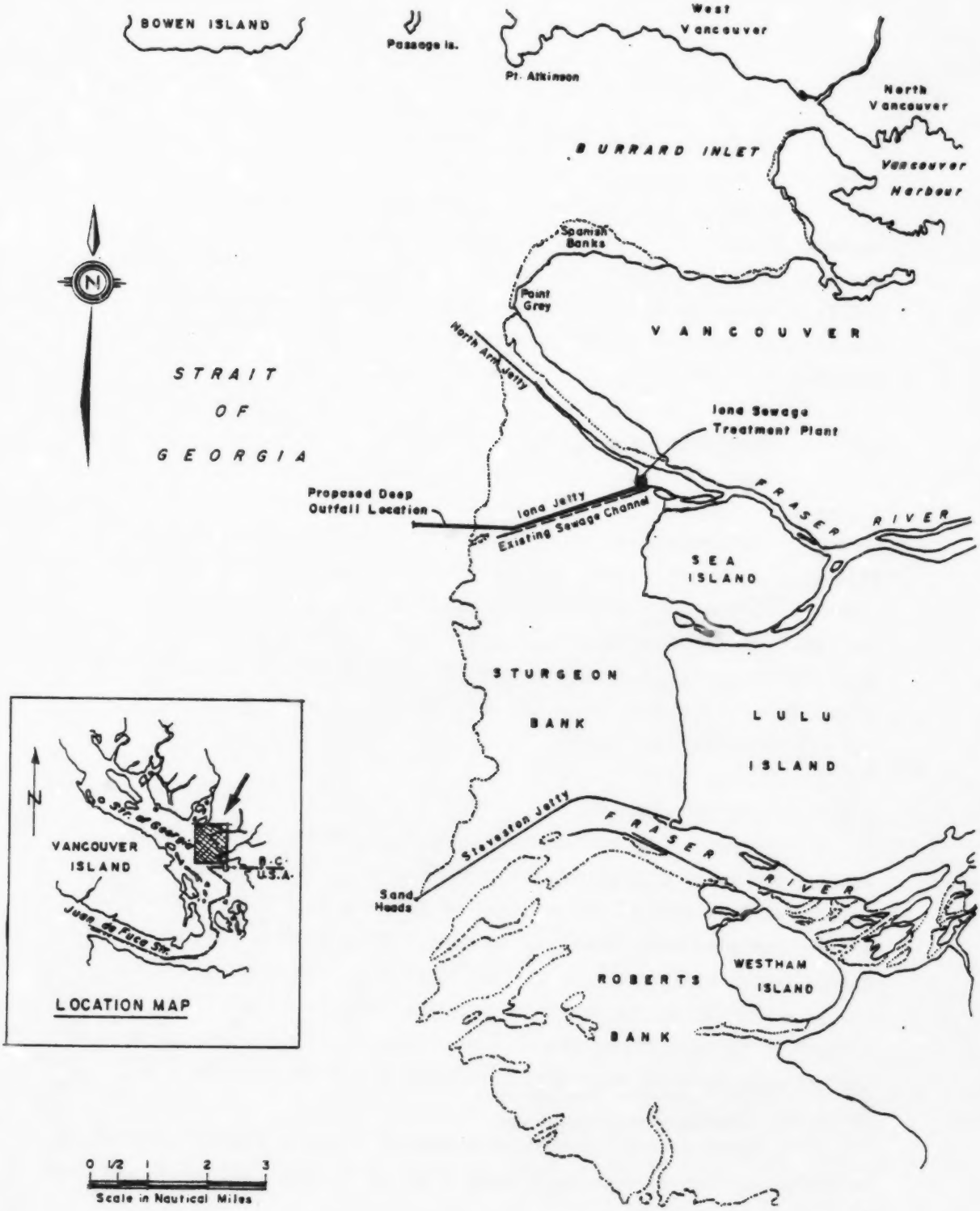

FIGURE I LOCATION MAP AND STUDY AREA

2. MATERIALS AND METHODS

Oceanographic and benthic sampling were conducted off Iona December 14-16, 1981 from the CSS VECTOR. A second survey March 11, 1982 was done to collect tissue for trace metal analysis. On July 15, 1982 the PISCES IV submersible was used to conduct a physical examination of the substrate in the area of the proposed sewage outfall. Station positions are given in Appendix I.

2.1 Oceanographic Sampling

Stations established by EPS in December, 1981 are shown in Figure 2.

Temperature and salinity profile data were obtained using a Plessy C.T.D. meter. Water samples for dissolved oxygen and nutrient (ammonia, nitrate, ortho-phosphate) analyses were collected in N.I.O. bottles. The azide modification of the Winkler method was used in determining dissolved oxygen concentrations (Swingle and Davidson, 1979). Dissolved nutrient concentrations were determined on an Autoanalyzer at the EPS chemistry laboratory.

2.2 Sediment Sampling

Grabs: A Smith-MacIntyre grab was used to obtain subtidal surface sediments at stations shown on Figure 2. Upon retrieval, subsamples were removed for analyses of particle size distribution, organic content, trace metal and mercury concentrations. Sediments were stored frozen until analyzed at the EPS chemistry laboratory.

Particle size distribution was determined by wet sieving through screens of 500 μm, 250 μm and 62.5 μm. Organic, trace metal and mercury content were measured according to methods described by Swingle and Davidson, (1979).

Benthic invertebrates were removed from 3 litres of sediment at selected stations by sieving through a 500 μm screen. The sample was then

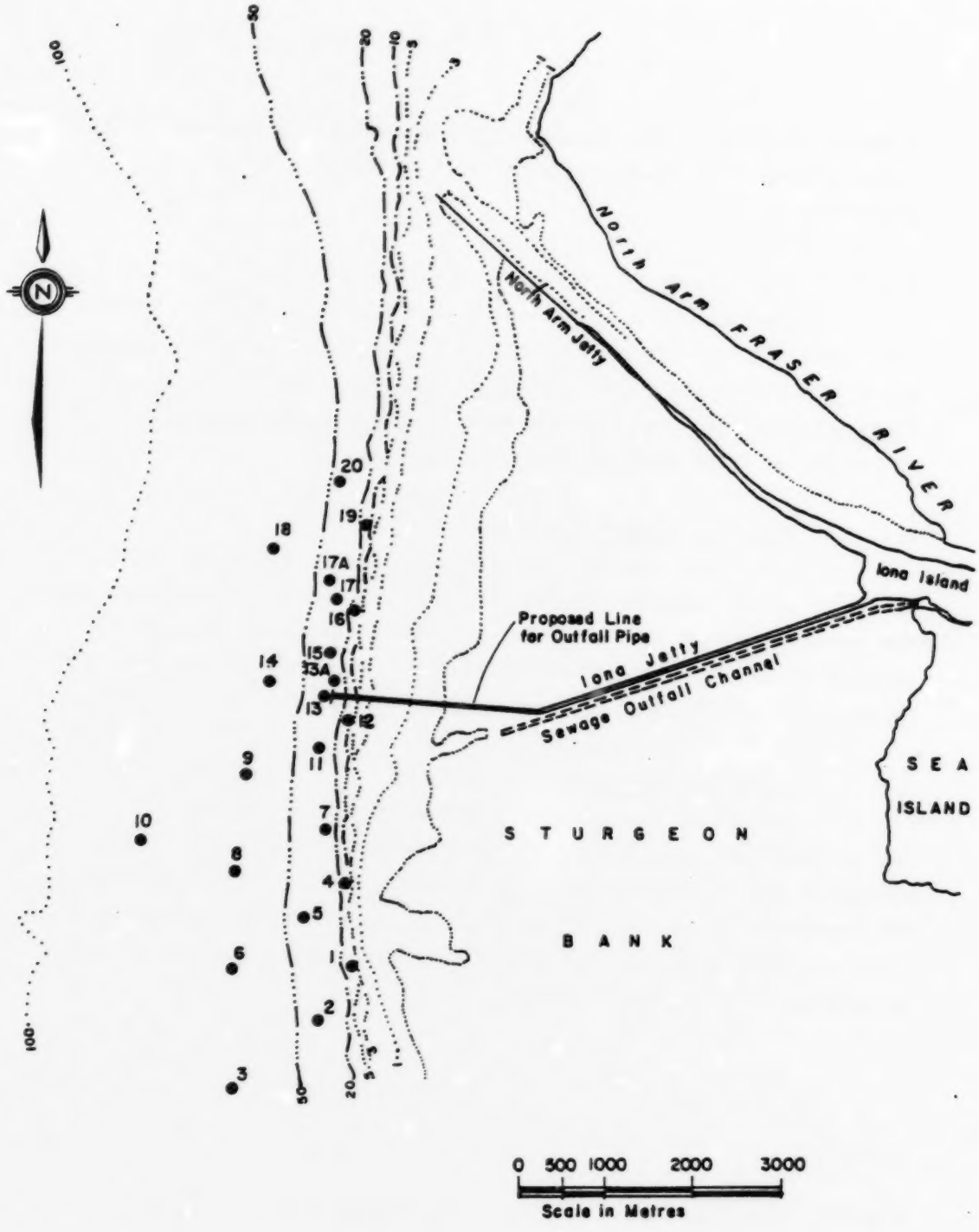

FIGURE 2 OCEANOGRAPHIC AND BENTHIC SAMPLING STATIONS

fixed in 10% formalin and subsequently preserved in 70% isopropanol for longer storage. Invertebrates were later sorted, identified and enumerated.

2.3 Otter Trawls

Invertebrate and fish tissue was obtained during March 1982 from two trawls off Iona (Figure 3). Muscle tissue from pink shrimp (Pandalus borealis), sidestripe shrimp (Pandalopsis dispar), spiny head sculpin (Dasycottus setiger) and flathead sole (Hippoglossoides elassodon) were collected for trace metal accumulation analysis.

2.4 PISCES IV Submersible Dives

A dive was made July 15, 1982 to visually assess the physical condition of the substrate in the area proposed for the diffuser and also the surrounding receiving environment. The approximate dive track is shown in Figure 4. Photographic records were made from inside the PISCES IV using a Bolex 16 mm movie camera and a Hasselblad 70 mm still camera.

2.5 Substrate Stability

Members of the Geological Survey of Canada, led by Dr. J. Luternauer, accompanied EPS on a portion of the December, 1981 survey to collect information on geomorphology. Substrate-slope stability and topography in the area of the proposed outfall were investigated using high resolution and side scan sonar techniques. Details of the study can be obtained from Dr. Luternauer[a].

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[a]Pacific Geoscience Center, PO Box 6000, Sidney, B.C.

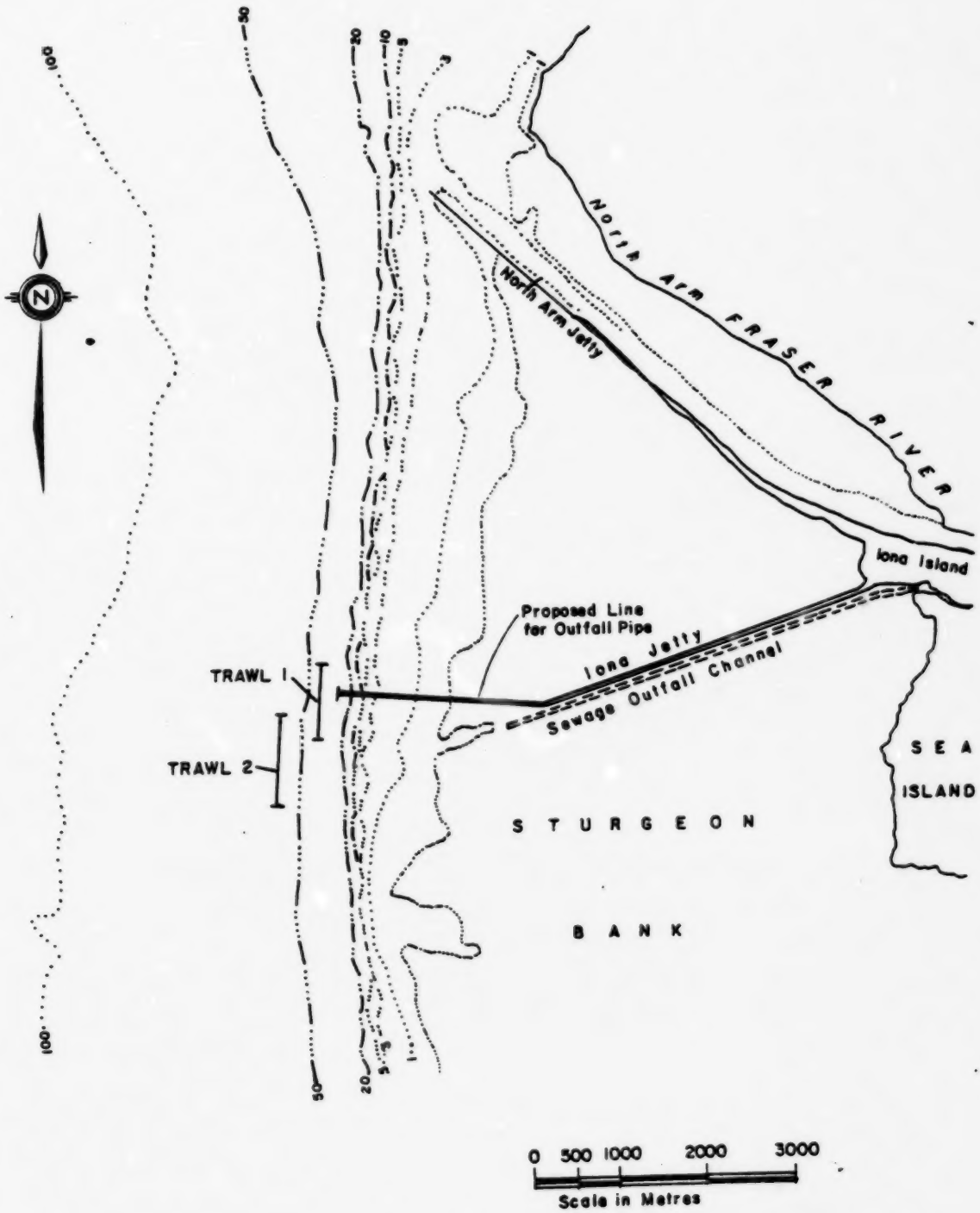

FIGURE 3 OTTER TRAWL TRACKS

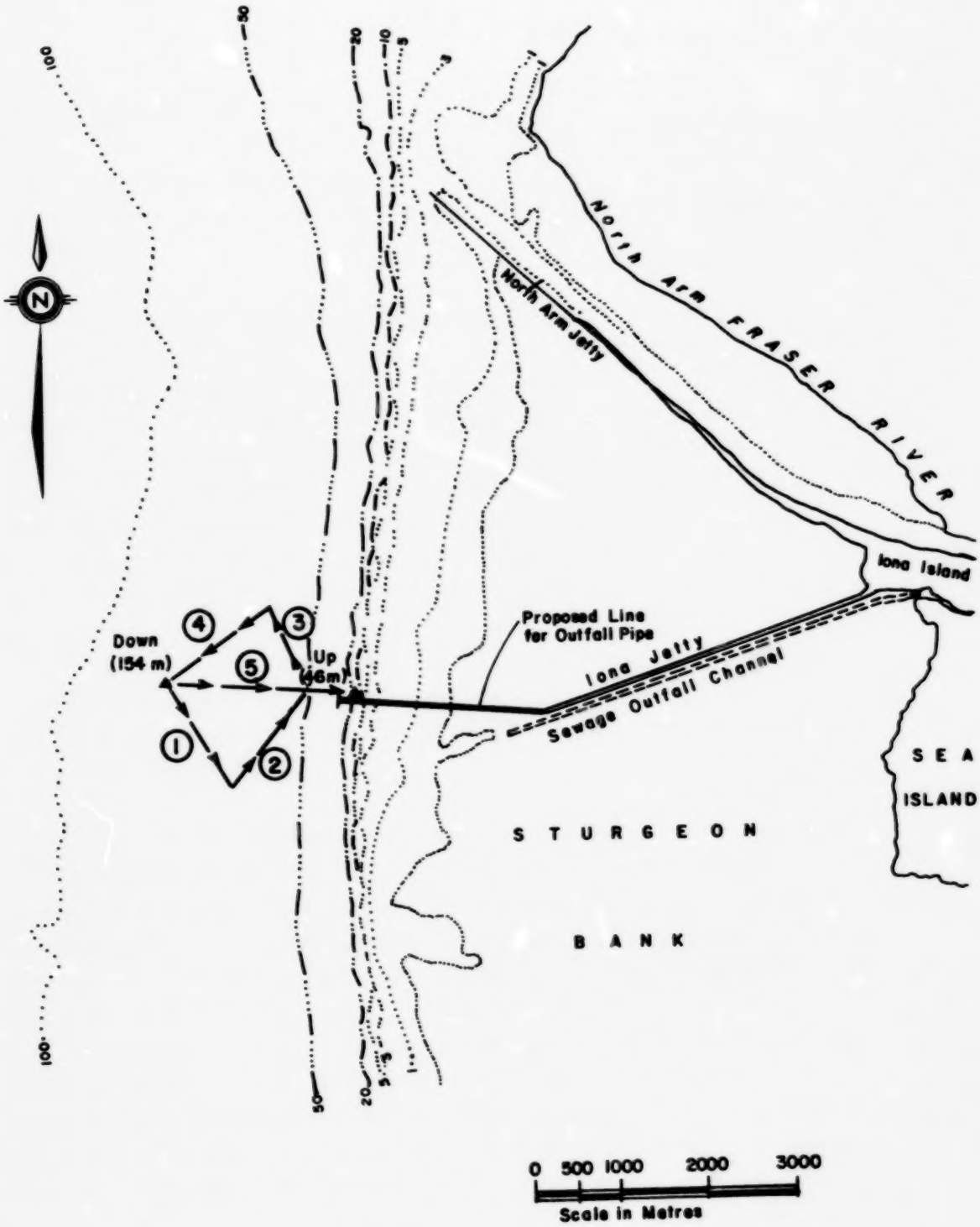

FIGURE 4 PISCES IV DIVE TRACKS

3. RESULTS AND DISCUSSION

3.1 Physical Oceanography

Data from oceanographic sampling are tabulated in Appendices II, III and IV.

3.1.1 Salinity, Temperature and Dissolved Oxygen. Vertical profiles of salinity, temperature and dissolved oxygen from December, 1981 (Appendix II) were characteristic of winter conditions in the Strait of Georgia-Fraser River estuary area. Surface cooling and the effect of cool river water were evident in the increasing salinity and temperature with depth. Spatial variation of these parameters were less at the bottom compared to the surface. Salinities ranged from 29.17 to 30.12 o/oo near bottom compared to 20.42 to 24.80 o/oo at the surface. No apparent pattern existed between salinity-temperature and proximity to direct river discharge or the existing sewage effluent channel.

Dissolved oxygen ranged from 10.0 to 7.8 mg/l at the surface and from 7.8 to 6.6 mg/l at the bottom over the study area (Appendix II). No depression was evident as has been documented in other studies nearer to the present sewage outfall.

3.1.2 Dissolved Nutrients. Ammonia, nitrate and ortho-phosphate levels recorded in December, 1981 were not abnormally high (Appendix III). Concentrations were comparable to those found in the Strait of Georgia and to those reported by Packman (1980) for the Point Grey-Iona area. Similar nutrient values have been recorded at other coastal sewage outfalls (Pomeroy and Packman 1981, Pomeroy 1982).

Ammonia levels in surface waters at stations 11 and 12, off the existing sewage channel, were elevated relative to other stations. An existing effluent effect is suggested with the potential for increased localized enrichment offshore during periods of low tide when the sewage channel is completely exposed.

3.2 Sediment Characteristics

3.2.1 Particle Size Distribution. Subtidal surface sediments in the study area were composed primarily of particles < 62.5 μm (Table 1). At all but Station 9, this size fraction accounted for 52 to 84% of a sediment sample. Shallower stations (19, 16, 12) tended to have higher percentages of < 62.5 μm compared to sediments from deeper waters. In addition, stations south of a line extending straight out from the existing sewage channel (4, 5, 7, 9, 9A) had lower percent composition of this size fraction compared to stations to the north. Flow from the sewage channel and the middle arm of the Fraser under the influence of a prevailing northerly current off Iona could account for the spatial variation.

3.2.2 Organic Content. Subtidal surface sediment organic carbon content ranged from 2.8% to 4.9% over the study area (Table 2). A relationship of increasing organics with increasing depth to the bottom was evident. As with particle size, a north/south variation was suggested with stations to the north of the proposed pipe having somewhat higher organic carbon content. This is not unexpected in view of the prevailing northerly currents off Iona.

The mean organic carbon content for surface sediments off Iona of 3.8% was higher than the 1.08% given by Pharo (1972) as an average for the Strait of Georgia. Loading from the sewage treatment plant and export from the extensive marsh lands of the Fraser are probable sources of the elevated organics.

3.2.3 Trace Metal Content. The results of surface sediment trace metal analyses are presented in Table 3.

Data suggest an effect of the existing sewage discharge and prevailing currents with higher levels of certain metals recorded at the more northerly stations. For example, lead (Pb) ranged from 166.0 ppm at

TABLE 1 PERCENT COMPOSITION OF SELECTED SIZE FRACTIONS OF SURFACE SEDIMENTS COLLECTED OFF IONA DECEMBER 14-16, 1981

STATION	DEPTH (m)	500 μm	500-250 μm	250-149 μm	149-62.5 μm	< 62.5 μm
4	42	0	2	3	42	53
5	80	8	14	7	23	56
7	61	0	6	7	24	63
9	95	0	20	9	32	39
9A	110	0	23	11	14	52
11	81	0	12	9	17	62
12	59	0	0	0	16	84
13	80	1	5	4	17	73
13A	78	1	6	4	18	71
15	83	1	5	5	17	72
16	74	0	3	3	13	81
17	86	2	8	6	16	68
19	60	1	4	4	14	77
20	100	1	9	6	15	69

TABLE 2 ORGANIC CARBON CONTENT OF SURFACE SEDIMENTS COLLECTED OFF IONA DECEMBER 14-16, 1981

STATION	DEPTH (m)	VOLATILE RESIDUE (%)
4	42	3.0
5	80	3.3
7	61	2.8
9	95	4.3
9A	110	4.7
11	81	3.9
12	59	3.3
13	80	3.8
13A	78	3.7
14	108	4.5
15	83	3.9
16	74	3.8
17	86	4.3
19	60	3.8
20	100	4.9

Station 15 (Figure 2) to 10.3 ppm at station 4 about 3 km to the south. Mercury (Hg) was highest (7.58 ppm) at station 13 at the end of the proposed outfall, dropping to < 0.164 ppm at station 7 to the south. At most stations values were < 0.7 ppm. Similar patterns existed for zinc (Zn), iron (Fe) and copper (Cu). Cadmium (Cd) was below the detection limit at all stations. Distance from shore and depth were not related to levels of trace metals.

Mean concentrations of certain sediment trace metals in the study area were generally higher than those recorded at other sewage outfalls on the coast of B.C. (Table 4).

3.3 Benthic Invertebrate Community

Initial sampling of the invertebrate community indicated dominance by polychaete worms and molluscs (Appendix VI). At station 12 in 59 m of water, the bivalve Thyasira sp. was dominant whereas at Station 13 and 17 in 80 and 86 m of water, polychaetes dominated the invertebrate community but to a lesser degree. Insufficient stations were sampled to permit further comments on variation in species composition of the invertebrate community.

Many species recorded at Iona were also found in the vicinity of outfalls near Nanaimo (Pomeroy and Packman, 1981) and Parksville (Pomeroy 1982) and at other areas of the coast not receiving sewage discharge.

3.4 Trace Metal Concentrations in Tissue

Data on the concentration of selected trace metals in shrimp and fish tissue are presented in Appendix VI.

The metal content of shrimp tissue differed between trawl 1 and trawl 2 done farther from shore. In the pink shrimp Pandalus borealis, metal concentrations were higher in those from trawl 1, while in Pandalopsis dispar the sidestripe shrimp, most metals were higher in organisms taken from trawl 2 done at a greater depth. Further studies are required to determine the reason behind this pattern.

TABLE 3 TRACE METAL CONCENTRATIONS OF SURFACE SEDIMENTS COLLECTED OFF IONA DECEMBER 14-16, 1981

STATION	DEPTH (m)	Hg (ppm)	Cd (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)
4	42	0.235	< 0.664	33.1	421.0	40.0	10.3	79.0	31100
5	80	0.316	< 0.648	37.4	452.0	39.3	13.0	84.5	33800
7	61	< 0.164	< 0.648	36.0	408.0	40.1	12.9	83.1	31600
9	95	0.316	< 0.660	40.8	447.0	42.6	15.2	90.9	34900
9A	110	0.516	< 0.658	44.0	502.0	43.5	15.0	96.5	38500
11	81	0.249	< 0.658	40.6	456.0	40.8	14.5	88.3	34700
12	59	1.670[b]	< 0.650	34.5	413.0	38.8	14.3	80.2	31600
13	80	7.580[b]	< 0.648	41.6	474.0	40.9	27.9	92.0	36600
13A	78	0.244	< 0.659	41.1	475.0	44.0	16.6	91.2	36000
14	108	0.724	< 0.657	46.3	509.0	44.1	17.4	102.0	39900
15	83	0.264[a]	< 0.658	47.0	505.0	44.6	166.0	100.0	40500
16	74	0.600	< 0.644	45.2	487.0	49.1	16.8	97.5	37400
17	86	0.583	< 0.658	45.1	473.0	42.4	17.2	95.2	36900
19	60	< 0.189	< 0.662	43.6	472.0	44.4	15.7	91.4	35800
20	100	0.249	< 0.653	43.6	494.0	43.1	15.2	93.5	37400

[a]100.0 ppm recorded in first sampling, level not approached in subsequent samples.

[b]Levels confirmed by repeating analysis.

TABLE 4 MEAN SURFACE SEDIMENT TRACE METAL CONCENTRATIONS AT IONA COMPARED TO THOSE RECORDED AT TWO COASTAL OUTFALLS

LOCATION	Hg (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (%)
Five Fingers Nanaimo - 1980 (outfall)	-	32.04	315.94	27.35	48.67	63.45	2.31
French Creek Parksville - 1980 (outfall)	-	10.27	197.61	10.57	23.86	23.24	1.48
Iona - 1981	1.040	41.30	466.00	42.50	25.90	91.00	3.58

Concentration of certain metals in P. borealis collected at Iona were comparable to or somewhat greater than levels recorded in the same species at other B.C. coast locations receiving domestic sewage (eg. Five Finger Island) and those relatively unimpacted by industrial activity such as Quatsino and Chatham Sounds (Table 5).

3.5 PISCES IV Observations (Appendix VIII)

The substrate on all dive tracks consisted of light brown unconsolidated mud and was generally featureless aside from numerous 2-3 cm diameter holes. No organic accumulations or reducing sediments were evident during the dive. Visibility on the botton at about 150 m was 1 metre, decreasing to about 0.3 metres in shallower waters.

Shrimp were present in small numbers in the deeper waters, becoming more frequent closer to shore. The same was true for crab and the few species of fish recorded during the dive.

TABLE 5 COMPARISON OF MEAN TRACE METAL CONCENTRATIONS (ppm dry weight) IN SHRIMP (*Pandalus borealis*) TISSUE COLLECTED AT IONA AND OTHER B.C. COAST LOCATIONS

	Cu	Cd	Pb	Zn	Ni	Fe
Pandalus borealis - pink shrimp						
1977 - Five Finger Island, Nanaimo	27.0	0.50	1.0	54.0	-	21.0
1981 - Chatham Sound[a]	20.7	0.11	0.09	52.6	3.90	18.3
1981 - Quatsino Sound[a]	21.5	0.07	0.13	52.1	3.90	20.8
1982 - Iona	25.9	0.49	1.0	55.2	1.92	31.9
Pandalopsis dispar - sidestripe shrimp						
1981 - Chatham Sound[a]	16.9	0.6	0.5	46.0	4.0	22.2
1981 - Chatham Sound[a]	23.1	0.6	0.6	47.8	3.9	19.4
1982 - Iona	27.7	0.3	1.0	53.83	1.84	26.26

[a]from Goyette and Christie, 1982

REFERENCES

Goyette, D. and P. Christie. Part I: Baseline Studies Amax/Kitsault Mine Sites - B.C. Molybdenum and Anyox, 1976-1980. EPS Regional Program Report 82-13 (1982).

Grieve, D. and K. Fletcher. Trace Metals in the Sediments of the Fraser River Delta Front, British Columbia. Department of Supply and Services Contract No. 015U-23233-4-0210 for Geological Survey of Canada. (1975).

Packman, G.A. An Environmental Assessment of the Point Grey Ocean Disposal Area in the Strait of Georgia, British Columbia. EPS. Regional Program Report: 80-3. (1980).

Pharo, C.H. Sediments of the Central and Southern Strait of Georgia, British Columbia. Ph.D Thesis, Department of Geology, University of British Columbia. (1972).

Pomeroy, W.M. Environmental Effects of a Deep Marine Sewage Outfall at Five Finger Island, Nanaimo, British Columbia, 1977-1980. EPS Regional Program Report 81-4.

Pomeroy, W.M. and G.A. Packman. Environmental Effects of a Deep Marine Sewage Outfall at Five Fingers Island, Nanaimo, British Columbia, 1977-1980. EPS Regional Program Report 81-4. (1981).

Pomeroy, W.M. Receiving Environment Conditions in the Vicinity of French Creek Sewage Outfall, Vancouver Island, B.C. (1977-1980). EPS Regional Program Report 82-12. (1982).

Swain, L.G. Fraser River Estuary Study: Water Quality. Industrial Effluents. Province of British Columbia. (1980).

Swingle, R.B. and J.W. Davidson. Laboratory Manual. Department of Environment, Environmental Protection Service. (1979).

Vernon, S.A., B. Talbot, T. Tevendale, D. Douglas and R. Rocchini. Report of the Iona Island Sewage Treatment Plant Study Group. Greater Vancouver Sewage and Drainage District Publication (April 1982).

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APPENDICES

APPENDIX I

STATION POSITIONS

APPENDIX I STATION POSITIONS

STATION	LATITUDE	LONGTITUDE
OCEANOGRAPHIC PROFILES AND BENTHIC GRABS		
1	49° 10.75' N	123° 17.60' W
2	49° 10.50' N	123° 18.50' W
3	49° 10.18' N	123° 18.60' W
4	49° 11.30' N	123° 17.67' W
5	49° 11.11' N	123° 17.99' W
6	49° 10.80' N	123° 18.70' W
7	49° 11.58' N	123° 17.80' W
8	49° 11.30' N	123° 18.70' W
9	49° 11.76' N	123° 18.14' W
10	49° 11.40' N	123° 19.40' W
11	49° 11.95' N	123° 17.95' W
12	49° 11.87' N	123° 17.77' W
13	49° 11.71' N	123° 17.93' W
13A	49° 12.42' N	123° 17.65' W
14	49° 12.34' N	123° 18.24' W
15	49° 12.55' N	123° 17.93' W
16	49° 12.95' N	123° 17.72' W
17	49° 13.06' N	123° 17.84' W
17A	49° 13.25' N	123° 17.95' W
18	49° 12.80' N	123° 18.65' W
19	49° 13.44' N	123° 17.56' W
20	49° 13.59' N	123° 17.85' W

TRAWL TRACKS

	START		STOP	
#1	49° 11.95' N	123° 17.95' W	49° 12.50' N	123° 17.85' W
#2	49° 11.75' N	123° 18.20' W	49° 12.18' N	123° 18.20' W

APPENDIX II

PHYSICAL OCEANOGRAPHIC DATA
December 14-15, 1981

APPENDIX II PHYSICAL OCEANOGRAPHIC DATA - December 14-15, 1981

STATION	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)
1	0	6.66	20.42	8.4
Dec. 15	2	6.67	-	-
1130 hrs.	5	7.01	-	-
	10	7.86	-	-
	20	8.46	-	7.5
	B=38	8.94	29.74	7.0
2	0	6.61	21.71	7.8
Dec. 14	2	6.63	-	-
1400 hrs.	5	6.76	-	-
	10	-	-	-
	25	8.70	-	-
	50	8.84	-	7.0
	85	8.98	29.92	7.0
	B=92			
3	0	6.66	20.14	8.4
Dec. 14	2	6.64	-	-
1430 hrs.	5	6.69	-	-
	10	7.97	-	-
	25	8.90	-	-
	50	8.95	-	7.8
	95	9.01	30.04	7.2
	B=114			
4	0	6.48	22.28	8.9
Dec. 15	2	5.56	-	-
1115 hrs.	5	6.74	-	-
	10	7.66	-	-
	20	8.84	-	7.1
	30	8.86	29.59	7.3
	B=36			
7	0	6.58	20.42	10.0
Dec. 14	2	6.77	-	-
1330 hrs.	5	8.02	-	-
	10	8.33	-	-
	25	8.69	-	-
	35	-	-	7.5
	50	8.97	-	-
	70	8.98	29.86	7.6
	B=106			

Continued...

APPENDIX II PHYSICAL OCEANOGRAPHIC DATA - December 14-15, 1981

(Continued)

STATION	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)
9 Dec. 14 1230 hrs.	0	6.94	20.97	-
	2	7.16	-	-
	5	7.37	-	-
	10	8.38	-	-
	25	9.02	-	-
	50	8.97	-	-
	95	9.05	29.99	
	B=110			9.8
11 Dec. 14 1300 hrs.	0	6.63	20.37	-
	2	6.98	-	-
	5	6.97	-	-
	10	8.29	-	-
	25	8.86	-	7.5
	35	-	-	-
	50	-	-	7.0
	B=72	9.00	29.88	
12 Dec. 15 1050 hrs.	0	5.60	21.87	9.1
	2	6.50	-	-
	5	6.97	-	-
	10	7.77	-	-
	18	-	-	8.2
	25	8.96	29.41	-
	B=36	-	-	6.6
13 Dec. 14 1140 hrs.	0	7.00	20.91	9.3
	2	6.97	-	-
	5	7.25	-	-
	10	8.31	-	-
	25	8.91	-	-
	38	-	-	7.6
	50	9.01	30.12	-
	B=75	-	-	6.8
15 Dec. 14 1115 hrs.	0	6.71	24.80	9.7
	2	6.88	-	-
	5	7.48	-	-
	10	8.10	-	-
	25	8.80	-	-
	45	9.01	-	7.6
	B=90	9.09	30.06	7.1

Continued...

APPENDIX II PHYSICAL OCEANOGRAPHIC DATA - December 14-15, 1981

(Continued)

STATION	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)
16	0	6.48	22.91	9.6
Dec. 15	2	6.51	-	-
1022 hrs.	5	7.04	-	-
	10	8.10	-	-
	17	-	-	7.4
	25	8.96	-	-
	35	9.00	30.10	7.2
	B=39			
19	0	6.42	22.18	9.5
Dec. 15	2	6.41	-	-
0952 hrs.	5	7.53	-	-
	10	8.49	-	-
	17	-	-	7.4
	25	8.95	-	-
	B=36	8.98	29.56	7.6
20	0	6.85	20.24	9.5
Dec. 14	2	7.33	-	-
1000 hrs.	5	7.49	-	-
	10	8.37	-	-
	25	8.82	-	-
	50	8.95	-	7.4
	B=95	9.02	29.17	7.3

B= bottom

APPENDIX III

DISSOLVED NUTRIENT DATA

APPENDIX III DISSOLVED NUTRIENT DATA - December 14-15, 1981

STATION	DEPTH (m)	AMMONIA (mg/L)	NITRATE (mg/L)	ORTHO-PHOSPHATE (mg/L)
1	0	0.0070	0.200	0.0420
	20 a	< 0.0050	0.352	0.0707
	38	< 0.0050	0.313	0.0644
2	0	0.0086	0.134	0.0350
	46	< 0.0050	0.273	0.0609
	92	< 0.0050	0.291	0.0670
4	0	0.0091	0.214	0.0430
	20	0.0053	0.265	0.0540
	30	< 0.0050	0.299	0.0633
7	0	0.0158	0.317	0.0528
	35	< 0.0050	0.370	0.0722
	70	< 0.0050	0.311	0.0681
11	0	0.0173	0.283	0.0480
	36	< 0.0050	0.370	0.0746
	72	< 0.0050	0.365	0.0769
12	0	0.0208	0.227	0.0480
	18	0.0088	0.235	0.0544
	36	< 0.0050	0.286	0.0620
13	0	0.0074	0.231	0.0460
	37	< 0.0050	0.287	0.0634
	75	< 0.0050	0.254	0.0590
15	0	0.0082	0.265	0.0592
	45	< 0.0050	0.275	0.0616
	90	< 0.0050	0.268	0.0617
16	0	0.0192	0.331	0.0589
	16	< 0.0050	0.341	0.0706
	32	< 0.0050	0.386	0.0767
19	0	0.0172	0.265	0.0460
	17	0.0062	0.348	0.0709
	36	< 0.0050	0.385	0.0764
20	0	0.0062	0.380	0.0770
	50	< 0.0050	0.265	0.0659
	100	0.0071	0.254	0.0525

a = mid water depth

APPENDIX IV

IDENTIFICATION OF BENTHIC FAUNA FROM SEDIMENT GRAB SAMPLES TAKEN DECEMBER 14-16, 1981

APPENDIX IV BENTHIC INVERTEBRATES IN SEDIMENT GRAB SAMPLES - STATION 12 (59 m)

INVERTEBRATE	NUMBER FOUND
ANNELIDA	
Cl. Polychaeta	
Sternaspis scutata	20
Myriochele oculata	2
Harmothoe imbricata	1
Peisidice ospera	3
Capitellidae	3
Lumbrineridae	12
Neptityidae	4
Glyceridae	5
Nereidae	2
Pectinariidae	1
Maldanidae	1
Sphaerodoridea	1
NEMERTEA	1
MOLLUSCA	
Cl. Bivalvia	
Pandora filosa	1
Yoldia sp.	5
Macoma sp.	6
Bivalve A	7
Bivalve B	18
Thyasira sp.	133
Cl. Aplacophora	
Chaetoderma sp.	3
ARTHROPODA	
Cl. Crustacea	
Ostracoda	2
Amphipoda	10
ECHINODERMATA	
Cl. Ophiuroidea	2

APPENDIX IV BENTHIC INVERTEBRATES IN SEDIMENT GRAB SAMPLES - STATION 13 (80 m)

INVERTEBRATE	NUMBER FOUND
ANNELIDA	
Cl. Polychaeta	2
Sternaspis scutata	3
Myriochele oculata	1
Glyceridae	1
Paraonidae	10
Lumbrineridae	3
Maldenidae (*Maldane glebifex*)	2
Orbiniidae	2
Phyllodocidae	1
Nephthyidae	1
Spionidae	
MOLLUSCA	
Cl. Bivalvia	2
Acila sp.	2
Yoldia sp.	16
Thyasira sp.	1
Macoma sp.	1
Bivalve A	2
Bivalve B	
Cl. Aplacophora	1
Chaetoderma sp.	
CRUSTACEA	2
Amphipoda	
ECHINODERMATA	5
Cl. Ophiuroidea	
Cl. Holothuroidea	1
Cucumaria miniata	2
Molpadia sp.	

APPENDIX IV BENTHIC INVERTEBRATES IN SEDIMENT GRAB SAMPLES - STATION 17 (86 m)

INVERTEBRATE	NUMBER FOUND
ANNELIDA	
Cl. Polychaeta	
Sternaspis scutata	3
Myriochele oculata	3
Pilargidae	1
Lumbrineridae	10
Onuphidae	2
Glyceridae	3
Maldonidae	2
Nereidae	1
Phyllodocidae	1
Spionidae	1
Orbiniidae	1
Opheliidae	1
Paraonidae	1
unknown Polychaetes	5
MOLLUSCA	
Cl. Bivalvia	
Cardiomya sp.	1
Macoma sp.	1
Thyasira sp.	8
Cl. Aplacophora	
Chaetoderma sp.	3
ARTHROPODA	
Cl. Crustacea	
Amphipoda	3
ECHINODERMATA	
Cl. Ophiuroidea	
Ophiuroidea	3
Cl. Holothuroidea	
Molpadia sp.	3

APPENDIX V

TRACE METAL CONCENTRATIONS IN TISSUES

APPENDIX V TRACE METAL CONCENTRATIONS IN TISSUES COLLECTED MARCH 9, 1982

SPECIES	Cd (ppm)		Cr (ppm)		Cu (ppm)		Mn (ppm)		Pb (ppm)		Zn (ppm)		Fe (ppm)		Hg (ppm)	Ni (ppm)	
	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry		wet	dry
									TRAN. 1								
Pandalus borealis	0.095	0.37	0.276	1.25	5.29	23.7	0.17	0.78	< 0.2	< 1.0	12.02	53.85	4.62	20.72	0.11[a] (0.09-0.13)	< 0.30	1.00
Pandalopsis dispar	0.070	0.30	0.363	1.88	4.94	21.8	0.15	0.68	0.25	1.0	11.68	51.68	6.56	28.93	0.12[a] (0.10-0.14)	0.46	2.16
Parophrys (w.s.)	0.03	0.20	0.550	2.80	1.74	8.7	0.38	1.92	0.20	1.0	7.01	35.0	5.33	26.7	0.14	1.0	5.00
vetulus (w.o.s.)	0.02	0.10	0.350	1.70	0.65	3.1	0.23	1.09	0.40	2.0	9.06	43.5	4.20	20.2	0.06	0.90	4.00
									TRAN. 2								
P. borealis	0.19	0.60	0.790	3.47	8.17	28.23	0.32	1.39	< 0.20	< 1.0	12.95	56.58	9.82	43.12	0.14[a] (0.12-0.18)	0.65	2.84
P. dispar	0.11	0.37	0.287	1.26	7.65	33.7	0.19	0.86	< 0.20	< 1.0	12.68	55.98	5.31	23.6	0.12[a] (0.08-0.16)	0.35	1.50
Dasycottus setiger	0.08	0.30	0.300	1.40	0.46	2.20	0.18	0.85	< 0.20	1.0	3.17	15.1	5.01	23.8	0.15	0.20	1.00

[a]mean of 6 samples, bracket = ranges

w.s. = with skin.

w.o.s. = without skin.

APPENDIX VI

PISCES IV DIVE REPORTS

PISCES IV DIVE REPORT

Location: Iona
Date: July 15, 1982
Time: 1813 up: 2130

TRACK 1-4

Depth: 155-142 m
Visibility: 1 m on bottom

Level light brown unconsolidated mud bottom with 30-50 holes/m^2 (2-3 cm diameter).

Pandalus borealis	- small numbers
P. platyceros	- small numbers
Cancer magister	- 6
Eel pout	- small numbers
Cod	- small numbers
Rockfish	- small numbers
Ratfish	- small numbers
Dogfish	- small numbers
Sole	- 5"-8" frequent, predominant fish noted in dive

TRACK 5

Depth: 152-40 m (up slope)
Visibility: 1 m to 0.3 m in shallow depths

Mud bottom as per Tracks 1-4.

P. borealis	- frequent
P. platyceros	- frequent
Cancer magister	- more frequent from 140 m up to 40 m at end of dive
Rockfish	- numerous
Dogfish	- small numbers
Sole	- frequent
Polychaetes	- numerous at 85 m

POOR

QUALITY

ORIGINAL